EFFECTIVENESS OF LAND MANAGEMENT PRACTICES AT KASHIMA FARM IN REDUCING SOIL COMPACTION, MAINTAINING SOIL ORGANIC MATTER AND WATER HOLDING CAPACITY.

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To you all, I salute you and may the heavenly God bless and multiply your days on earth.

ABSTRACT

Improper use of heavy agricultural machinery and equipment has often been the cause of soil compaction, loss of soil organic matter and reduced soil water retention. In Zambia, this is slowly becoming the case. This study was conducted to assess the effectiveness of the land management practices done at Kashima farm in reducing soil compaction, maintaining soil organic matter and water holding capacity.

Kashima farm was chosen as a study area due to its use of heavy machinery and equipment for a long time. They also carry out remedial measures like ripping every time when preparing land for cropping. Baby corn stover is threshed and incorporated into the soil to boost soil organic matter. A site was chosen with the help of management. Two plots: cultivated and uncultivated land was chosen for comparisons. A survey was conducted to determine uniformity of soil between cultivated land and adjacent uncultivated land. Uncultivated land was used as the control.

From each plot, two samples were collected at four locations from five different depths;0-10cm, 10-20cm, 20-30cm, 30-40cm and 40-50cm. A disturbed sample was collected for organic matter and particle size analysis while an undisturbed sample was collected for bulk density and water holding capacity determinations. The samples were then taken to the laboratory for various analyses. Results were statistically analysed to determine differences in the mean values of cultivated with the uncultivated land at p=0.05.

Results showed that uncultivated land had higher organic matter content than uncultivated land. They further indicated that bulk densities were higher in the top 0-20cm for uncultivated land while, they were lower in the top 0-30cm for cultivated land. At 20-30cm and 30-40cm uncultivated land had significantly lower bulk densities than cultivated land. For water holding capacity and soil texture, there were no significant differences in the mean values.

On the basis of the results, it has been observed that that the land management measures taken at Kashima farm are effective in maintaining water holding capacity and reducing soil compaction from 0-30cm. However, they are not effective in maintaining soil organic matter and reducing soil compaction at 30-40cm.

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CHAPTER ONE

1.0 INTRODUCTION

The improvement in the technology and the liberalisation of the agricultural sector with persistence of animal diseases has led to an increase in the use agricultural machinery and equipment in the farming sector in Zambia. This in turn has reduced farm labour as most operations are mechanised. The use of heavy machinery for agricultural operations with bad management can lead to severe soil deterioration such as a decline in soil aggregation and compaction of soil (Forth *et. al.* 1965).

Soil compaction is the increase in the bulk density of the soil. This happens by reduction of soil voids (Miller *et. al.* 1995). This happens in several ways. Tillage tools can affect soil properties in many ways, some of which include compaction, shearing, lifting, sliding, throwing, inversion and mixing of the solid mass. As a wedge moves through the soil, it causes repetitive compression and shearing of soil blocks. Soil moisture is one of the most important physical properties, which determine the nature of the soil reaction to a tillage tool. This is because it affects the consistency of the soil.

Soil compaction is the same whether it is caused by long time of cropping or traffic involving tractor tyres, animal hooves or shoes. Compaction at the bottom of the furrows frequently occurs during ploughing because of the running of the tractor wheels in the furrows made by the previous pass over the field. Subsequent tillage is usually too shallow to break up the compacted soils, and compaction increases with time. This type of compaction produces a layer with high bulk density at the bottom of the plough layer and is appropriately termed a plough sole or plough pan (Forth, *et. al.,* 1965).

In most cases, soil compaction has a negative relation with soils organic matter and the water holding capacity of the soil. According to Hurni and Tato,(1992), who said when bulk density increases, the water holding capacity decreases because the soil become more compact, thereby reducing the infiltration capacity of the soils and consequently the amount of water present in the soil. The highly compacted topsoil further limits water movement into the subsoil. Constraints in the soil physical conditions are as crucial to the growth of crops as chemical fertility.

Allison (1973) suggested that soil organic matter is what is often markedly affected by the treatment that the soil receives at the hands of the agriculturist responsible for the crop and soil management. It is the mouldboard plough and the various systems of cultivation that keeps the soil bare for a considerable portion of the year that are primarily responsible for marked decreases in soil organic matter following the breaking of virgin land.

1.1 Problem statement

Through discussions with a number of farmers around Mpongwe, Lusaka and Kabwe who use farm machinery such as tractors, trucks and so on , it was learnt that soil compaction was becoming a problem at most of these farms. If crop production is to remain sustainable in Zambia, there is need to practice good tillage operations and to identify methods for correcting soil compaction where it exists as it both increases costs of production and by diminishing yields, also lowers total returns, thus putting profit in a double squeeze. According to my observations, the crop residue of Baby corn trash is incorporated into the fields and minimum tillage is practiced where possible. Each field is ripped every time land is being prepared. This study was conducted at Kashima Farm, which uses heavy agricultural machinery and equipment like tractors, trucks, planters, and many more, but with remedial measures.

1.2 Objectives

The objectives of the study were:

(a) To assess and compare levels of soil compaction between cultivated soils and adjacent uncultivated soils by measuring the bulk density

(b) To determine and compare the distribution of soil organic carbon in the top 50cm of cultivated and uncultivated land

(c) To determine and compare the soil moisture characteristic curves of the cultivated soils and adjacent uncultivated soils.

1.3 Hypotheses

The hypotheses of the study were that:

(a) Soils in the cultivated fields have higher bulk densities hence, are more compacted than those from adjacent uncultivated land.

(b) The soil organic matter of uncultivated land has higher organic matter and well distributed than the uncultivated land.

(c) The water holding capacity of the soils in cultivated land is lower than that from the adjacent uncultivated land.

1.4 Justification of the hypotheses

Soils that are under cultivation with heavy machinery should have high bulk densities meaning the soils are compacted. This is because in commercial farming sometimes you do not observe the soil condition as to when to plough due to non-availability of time to wait for the soils to reach optimal moisture content. I also feel there is a direct relationship between compaction and organic matter content because compacted soils will hold less water which also reduces the activity of the micro-organisms that decompose organic matter and decline in soil organic matter content, degradation of soil structure and drying accompanied by high soil temperatures encourage consolidation and compression. The smearing and compacting action of the plough sole gives rise to pore discontinuity that inhibits water movement and root development.

CHAPTER TWO

2.0 LITERATURE REVIEW

The soils have a rapid permeability, receive precipitation-averaging 800mm. Bulk density values are needed to calculate storage capacity of water per soil volume, and soil layers can be evaluated to determine if they are too compacted to allow root penetration. Soil compaction also impedes the movement of water and air through the soil by reducing the number of larger pores (porosity). Volumes of compaction in the soil typically reduce the volume of the soil tapped by the root system of the plant. The pore space (also called void) in a soil consists of that portion of the soil volume not occupied by solids, either mineral or organic (Miller *et. al.,* 1995).

Kepner *et. al.,* (1972) reported that the approach to soil structure management conceives of a field typically planted to row crops as consisting of at least two distinct different zones:

(i) a planting zone, where conditions are to be optimal for sowing and conducive to rapid and complete germination and seedling establishment

(ii) a management zone in the inter- row areas, where soil structure is to be coarse and open, allowing maximal intake of water and air, and minimal erosion and weed infestation.

Hillel (1980) points out that recent trends in tillage research have been aimed at maximising tillage operations and travel both to reduce costs and to avoid soil compaction while tailoring each operation to its specific zone and objective. This is done by leaving crop residues over the surface as a stubble mulch to protect against evaporation and erosion or incorporating it with soil to boost organic matter as soils with low organic matter contents and unsuitable aggregates are partially vulnerable to compaction, and erosion.

The ideal conditions for a seedbed are that it should consist of soil crumbs none much finer than 0.5 mm to 1 mm, and none much coarser than 5 to 6 mm in fairly firm packing. Finer crumbs will block the coarser pores needed for drainage and coarser crumbs are likely to have anaerobic centres during wet weather. The trend to reduce labour on a farm by use of larger and heavier machinery increases the likelihood and damage of untimely cultivation and the frequency of traffic over soil. Especially insidious is the common practice of ploughing with the tractor wheel running over the bottom of the open furrow where the soil is likely o be even more compatible than at the surface and to greater depth, owing to higher moisture and lower organic matter content. Furthermore, compaction in depth is much more difficult to rectify and hence longer lasting than compaction on the surface.

Bruce and Tailor (1968) elaborated that compaction is not limited to initial ploughing but traversing of the soil surface by tractor wheels during the traditional preparation of the seedbed can cause 90% of compaction, followed by a further trampling of at least 25% of the soil during combine harvesting and as much as 60% where straw is baled and carted off. Compaction caused by this traffic, particularly during seedbed operations, can increase bulk density to a depth of at least 30cm and can remain through out the life of the crop. Especially damaging is cultivating a clayey soil with heavy equipment when the soil is at a wet state and its strength is low.

He further went on to note that roots are unable to decrease in diameter to enter pores narrower than their root caps, thus, if they are to grow through compacted soils they must displace soil particles to widen the pores by exerting a pressure greater than the soils mechanical strength.

Soil organic matter is important because it determines the capacity of soils retention of plant nutrient and besides, it also contains many plant nutrients such as phosphorus, nitrogen, sulphur, potassium and magnesium which are released during the mineralization of the soils organic matter. In addition, it also influences other physical properties such as porosity of the soils, crumb structure and the water holding capacity of the soils. Therefore, in areas dominated by low activity clays (e.g. kaolinite), the role of other soil properties, especially the soil organic matter, cannot be under estimated (Hurni, *et. al.*, 1992).

Morgan (1986) emphasized the importance of organic matter that it improves the cohesiveness of the soil, increases its water retention capacity and promotes a stable aggregate structure. It may be added as green manure, straw or as manure, which has already undergone a high degree of fermentation. He stated that soils with less than 2% organic content are generally erodable. Organic materials that serve as precursors of soil humus may reach the soil in the forms of whole plants and animals; as fractions of the original plants and animals such as starch, protein, cellulose, or as partially decomposed mixtures of the original plant materials. The soils humus sources include chiefly such materials as crop residues including plant roots, animal manure, green manure, artificial manure and composts, dead animals, organic fertilisers and microorganisms.

The organic matter level is usually higher in undisturbed soils because all native vegetation remains on the soil, erosion is negligible and oxidation is at a minimum. Under cultivation, much of the vegetation produced is removed, water and wind erosion are tremendously accelerated, and frequent cultivation favour the destructive processes. Erosion if not controlled is one of the major reasons for marked decreases in organic matter in the soil.

He further went on to states that the organic matter in eroded material may be as much as five times higher than in the soil that remains. The harmful effect of continuous clean cultivation on soil organic matter can be greatly reduced by the adoption of a cropping system that reduces the number of cultivation and keeps the soil protected by vegetation as much of the time as possible.

Wischmeier and Mannering (1965) noted that the effect of cultivation on aggregation is closely dependent upon the amount of moisture present at the time of cultivation. Other factors involved include kind of soil, amount of organic matter present, intensity of cultivation and the amount of compaction involved. Cultivation brings the soil particles closer together, thereby increasing the binding forces that favour aggregate formation, but such newly formed aggregates may show little water-stability. Cultivation of soils is usually injurious to aggregation if the soils are too wet. Under such conditions, partial pudding can occur and the result on drying may be a very compact cloddy, poor aerated soil. The presence of abundant organic matter markedly decreases any harmful effects of cultivation. Increasing the content of the decomposed and partially decomposed organic residues substantially increases infiltration into moist soils. Organic matter increases infiltration by helping to hold water on the soil surface long enough for it to seep into the soil, and by improving the physical conditions of the soil. When a fine textured soil is left bare, the raindrop impact at the surface destroys most of the surface soil aggregates and when it dries crust formation is the result. Most of the physical effects that organic matter exerts in the soils are realised through the formation and stabilisation of aggregates. The emphasis is on very stable aggregates, not only stable against water but also at least fairly resistant to mechanical disturbance and other changes in soils with time. The gentleman went on to note that fertilisers applied as a supplement to proper cropping systems can go for toward maintaining soil organic matter.

This is obvious since they increase plant growth and this means more crop residues including roots will be turned into soil. The addition of the necessary nutrients, including lime if needed, can go far towards offsetting the degrading effect of cultivation on soil organic matter, not by stopping the oxidation but by increasing yields and thereby supplying more carbon containing compounds to replace those being oxidised.

Lenvain (1985) in his article on the evaluation of soil physical properties observed that in the advanced stages of weathering the loss of physical fertility is considerable. This is extremely important for agricultural sector since tillage, irrigation and crop management depend on the level of physical fertility. He further went on to observe that it is important to have a complete plant cover on the soil, which serves to break the impact of the raindrops and keeps the soil open and porous. Organic matter mixed with the soil also aids greatly in increasing infiltration by helping to provide better aggregation and structure, and consequently, lower bulk density and increase ease of water movement and stability.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Selection of fields and soil sampling

A field, which has been under cultivation for a long time, was chosen (Field 3/2B & 3/1B). This field was selected because it is farmed most of the year i.e. both under rainfall and irrigation hence, have been traversed more than those which have one crop per year (under rainfall). Besides, this field is among the oldest on the farm. For the control, soils in the adjacent former cattle paddock were used. In the field, four (4) random samples were collected for analysis of each parameter. Each sample was collected at five different depths; 0-10 cm, 10cm - 20cm, 20cm - 30cm, 30 cm -40cm and 40 cm - 50cm. The soil core rings were used for one sample (bulk density and water holding capacity) while the soil auger was used for the other sample. The core rings with undisturbed soil were labelled and their numbers written down in the field book. For organic matter and soil texture, samples were collected ii plastic bags weighing between 100 to200g.

3.2 Soil Sample Preparation

The samples for organic matter content were then air dried, after which they were crushed in a mortar to break down the soil aggregates. They were then sieved using a 2mm sieve.

3.3 Sample Analysis

3.3.1 Bulk Density (B_d)

In determination of the bulk density, the samples were oven dried to a constant weight at 105^{0}C for 24 hours. The weight of the sample measured and the oven dry mass was calculated by subtracting the mass of the core ring from the mass of the sample plus core ring. The volume of the sample was determined by calculating the inner volume of the core ring using the following formula:

$V=\pi r^2 l$

Where; V-volume (cm^3)

π-constant

r-radius of the inner core ring (cm)

l-height of the core ring (cm)

The bulk density is then calculated using the following formula:

$$B_d = \frac{\text{mass of oven dry soil}}{\text{volume of oven dry soil}}$$

3.3.2 Organic Matter Content (OM)

The *Walkley and Black* method was used as tabulated in Lab. Manual (Songolo, *et al*, 1992).

3.3.3 Water Holding Capacity

An undisturbed soil sample was taken from the field, in cylindrical core rings. Using an insert, which fits exactly in the core ring, the sample was pushed out of the core for exactly 1 cm. This 1cm slice was cut using a straight edge knife. The slice obtained at first was discarded. Another 1cm slice was pushed out, using the insert.

A label was put on the soil retainer and the labelled rubber ring was put around the extended slice. The extended slice was cut and the 1 cm thick slice had to be handled with extreme care. The samples are brought to pressure plate apparatus and are then placed on the plate inside the chamber. These samples were saturated for 24 hours before being subjected to suction pressure for another 24 hours after which they will be removed, measured and oven dried for another 24 hours at 105°C in the oven. This was determined at five suctions: 0.1 bar, 0.3 bar (field capacity: FC), 2 bars, 5 bars, 9 bars and 15 bars (wilting point). The plant available water was then calculated as follows;

PAW = FC - WP

The wilting point for plants is at 15 bars

PAW = water left after suction of F.C. is applied minus that left after suction of 15 bars is applied (WP).

3.3.4 Moisture Characteristic Curves

These are graphical analysis of soil water holding capacity, which are plots of suction pressure against soil moisture content.

3.4 Statistical Analysis

Results of the various samples of the soil were analysed statistically using the ANOVA and compared whether there were statistically significant differences between those from the field with those of the uncultivated soils. These results helped draw conclusions and recommendations where possible. The level of confidence was 0.05(5%).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Organic matter

Figure 1 below shows the mean values of soil organic matter content of cultivated and uncultivated land at Kashima Farm.

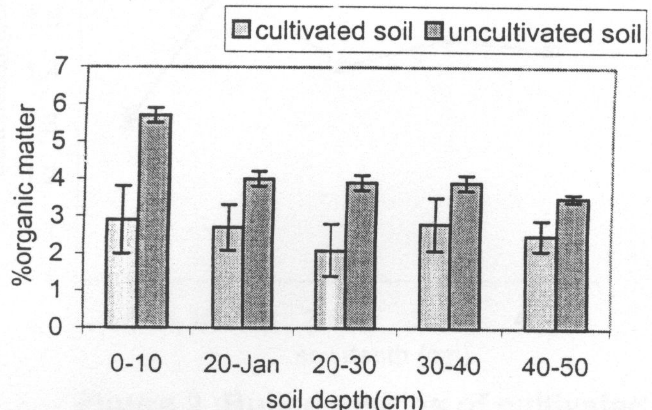


Figure 1:Organic matter content of cultivated and uncultivated soil at Kashima Farm

The results show that uncultivated land generally had higher organic matter content than the uncultivated land. Results of Analysis of Variance (ANOVA) confirmed that there were significant differences between mean values of cultivated and uncultivated land at the depths considered.

The low organic matter content of the cultivated land could be attributed to the loss of carbon as CO_2 gas The loss is enhanced due to aeration which increases microbial activity thereby increasing carbon oxidation as stated by Reicosky (1988). He further went on to report that less intensive strip tillage increases the sequestration of soil carbon due less disturbance to the soil thereby reducing the frequency with which organic matter is exposed to micro organisms for decomposition.

The results strongly substantiates Allison's (1973) earlier suggestion that organic matter of the soil is often affected by the treatment that the soil receives at the hands of the agriculturalists responsible for crop and soil management.

4.2 Bulk Density

Figure 2 below shows that the results of cultivated and uncultivated land.

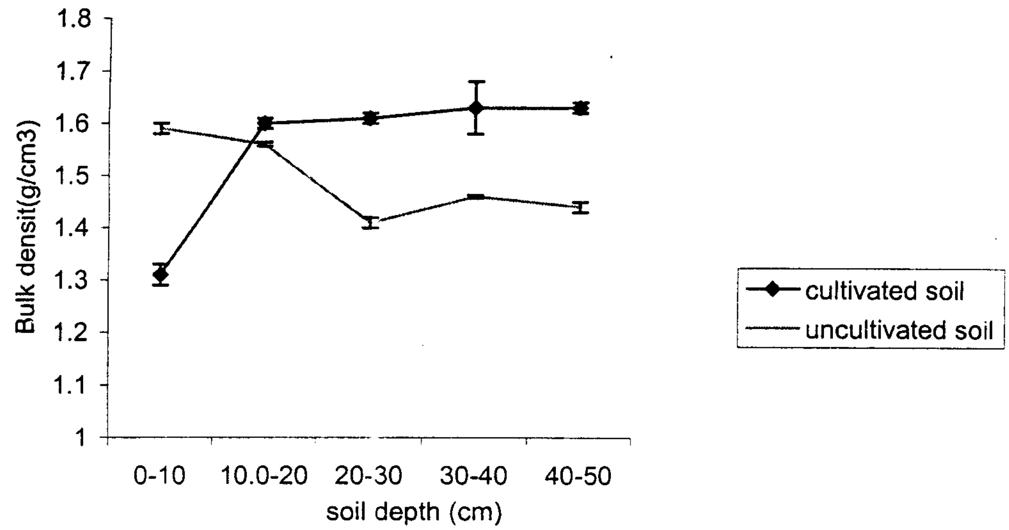


Figure 2 :Bulk densities of cultivated and uncultivated soil at Kashima Farm

From the results it can be deduced that bulk density for cultivated land increases from 0-20cm and then remains constant while for the uncultivated soil it decreases from 0-40cm and remains constant. When the results were analysed statistically using ANOVA, it was found that the bulk density at depth 0-10cm yielded significant differences. So did 20-30cm and 30-40cm.

The reasons behind the increase in bulk density for the cultivated land could be due to the impact of use of heavy machinery and the low organic matter content of the soil (Bruce and Tailor, 1968). They stated that organic matter content besides helping hold water, cushions soil compaction due to it behaving like "foam". There is risk of a hardpan forming at about 40cm if the ripping depth is not increased.

The low bulk density at 0-10cm of cultivated land could be attributed to the fact that even if minimum tillage is practised, this depth of soil is disturbed and this is the reason why bulk density is increasing with depth, while on uncultivated land it is decreasing with depth. The high bulk density of uncultivated land in the top horizons could be due to compaction caused by trampling on by cattle that used to be kept on the land. The reduction in bulk density on uncultivated land is sufficed by the fact total porosity increases with depth (Hillel, 1981).

4.3 Water Holding Capacity

Figure 3 shows the mean values of water holding capacity of soils at different depths.

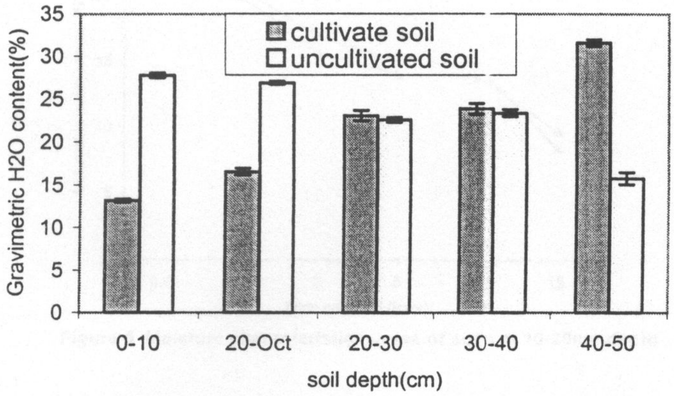
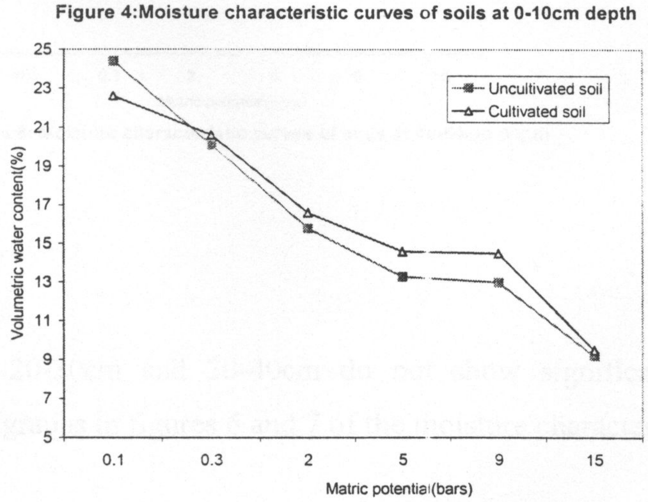


Figure 3 :Water holding capacity of cultivated and uncultivated soils at Kashima Farm

It shows that the water holding capacity of cultivated land increases with depth while that for uncultivated land decreases with soil depth.

The results of Analysis of Variance indicate that there are significant differences at 0-10cm, 10-20cm and 40-50cm.This are even confirmed in the soil moisture characteristic curves (figures 4,5,and 8).

Figure 4:Moisture characteristic curves of soils at 0-10cm depth



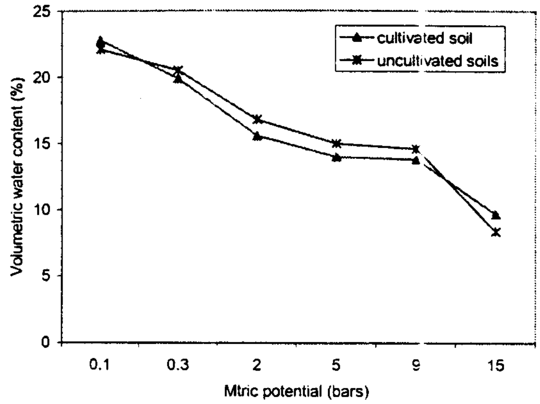


Figure 5 :Moisture characteristic curves of soils at 10-20cm depth

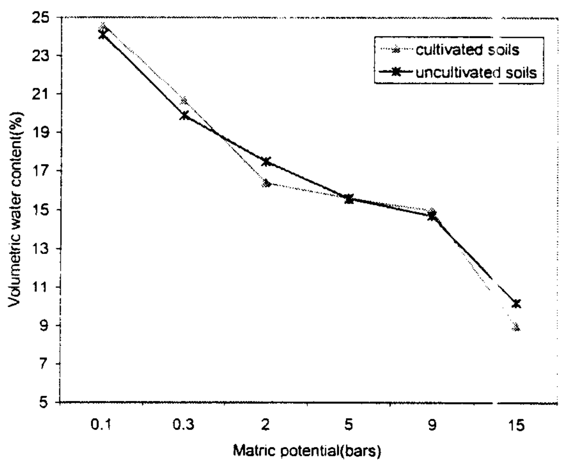


Figure 8: Moisture characteristic curves of soils at 40-50cm depth

The soil depths 20-30cm and 30-40cm do not show significant differences and are also confirmed by the graphs in figures 6 and 7 of the moisture characteristic curves below.

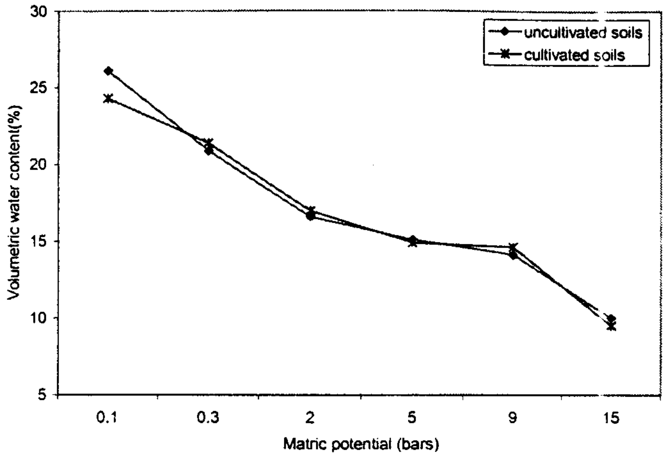


Figure 6 : Moisture characteristic curves of soils at 20-30cm depth

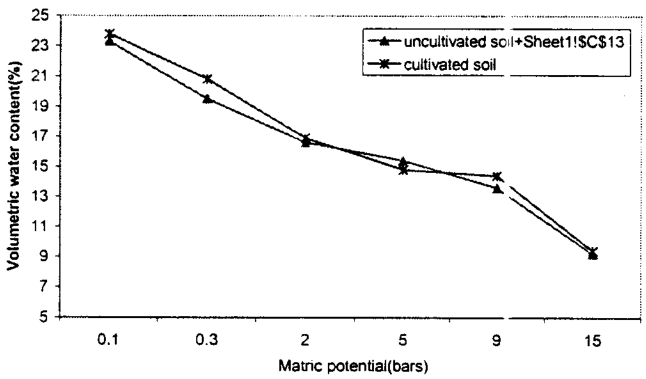


Figure 7 :Moisture characteristic curves at 30-40cm soil depth

The reasons for the high water holding capacity of uncultivated soil could be due to high content of organic matter while the cultivated soil has low water holding capacity coinciding with the low contents of organic matter as stated by Morgan (1986) that organic matter improves the water retention capacity of the soil.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

Based on the results of this study, the following conclusions have been made regarding the hypotheses that were tested at Kashima farm. The first is that soil from cultivated land has higher bulk densities than that from uncultivated land except at 10-20cm and 40-50cm soil depth. Secondly, soil organic matter of cultivated land is higher than that of the uncultivated land at all depths, and thirdly, that there are no significant differences in water holding capacities of cultivated land compared with the uncultivated land. On the basis of the findings, it can further be concluded that the land management practices at Kashima farm are quite effective in reducing soil compaction in the top 30cm soil depth and in maintaining water-holding capacity of the soil. But they are not effective in reducing soil compaction at 30-40cm.

For these practices to be effective, management should consider increasing the ripping depth to about 45cm as they risk forming a hardpan at 40cm with time if they continue with the current practices as can be seen from the high bulk densities at that depth. The current ripping depths are quite shallow .The other alternative is to maintain the ripping depths but increase on the cross ripping to a depth of about 45-50cm.

Finally, I recommend that similar studies be carried out on different farms across the agro-ecological zones of Zambia.

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APPENDICES

Table 1: Summary of results for cultivated and uncultivated land at Kashima farm

CULTIVATED LAND									
Soil Depth (cm)	Clay Content (%)	Bulk density (g/cm^3)		Water Holding Capacity (%)		Total Porosity (%)	Organic Matter Content (%)	
		M	SE	MEAN	SE		MEAN	SE
0 – 10	31.3	1.31	0.02	10.9	0.16	50.6	2.90	0.92
10 – 20	31.3	1.60	0.01	10.2	0.35	39.6	2.74	0.60
20 – 30	27.0	1.61	0.01	10.9	0.60	39.2	2.07	0.66
30 – 40	31.0	1.63	0.05	10.3	0.60	38.5	2.79	0.66
40 – 50	33.0	1.63	0.01	10.7	0.37	38.5	2.47	0.43
UNCULTIVATED LAND								
0 – 10	29.0	1.59	0.01	11.1	0.30	40.0	5.73	0.23
10 – 20	28.0	1.56	0.004	12.1	0.20	41.1	3.97	0.25
20 – 30	22.4	1.41	0.01	11.9	0.30	46.8	3.91	0.17
30 – 40	29.0	1.46	0.003	11.4	0.44	44.9	3.90	0.15
40 – 50	30.3	1.44	0.01	13.9	0.67	45.6	3.47	0.11

Soil depth(cm)	Cultivated land	Uncultivated land
0-10	1.31a	1.59b
10-20	1.60a	1.56a
20-30	1.61a	1.41b
30-40	1.63a	1.46b
40-50	1.63a	1.44a

Table 2: Mean values of bulk density (g/cm^3) of cultivated and uncultivated land.

(Numbers followed by the same letter along the row implies that the mean values are not significantly different at 5% confidence level)

Soil depth (cm)	Cultivated land	Uncultivated land
0-10	2.90b	5.73a
10-20	2.74b	3.97a
20-30	2.07b	3.91a
30-40	2.79b	3.90a
40-50	2.49b	3.47a

Table 3: Mean values of organic matter content of cultivated and uncultivated land

(Numbers followed by the same letter along the row implies that the mean values are not significantly different at 5% confidence level)

Soil depth (cm)	Cultivated land	Uncultivated land
0-10	13.2a	27.9a
10-20	16.6a	26.9a
20-30	23.1a	22.6a
30-40	23.9a	23.4a
40-50	31.6a	15.8a

Table 4: Mean values of water holding capacity of cultivated (%)

and uncultivated land

(Numbers followed by the same letter along the row implies that the mean values are not significantly different at 5% confidence level)

Soil depth (cm)	Cultivated land	Uncultivated land
0-10	31.3a	29.0a
10-20	31.3a	28.0a
20-30	27.0a	22.4a
30-40	31.0a	29.0a
40-50	33.0a	30.0a

Table 5: Mean values of clay content (%) of cultivated and uncultivated land

(Numbers followed by the same letter along the row implies that the mean values are not significantly different at 5% confidence level)

Appendix 1 A: ANOVA for organic matter at soil depth 0-10cm

Source of Variation	Degree of freedom	Sum of Squares	Mean Squares	Observed F	F-Table
Total	7	26.76			
Treatment	1	15.99	15.99	8.88	5.99
Error	6	10.77	1.80		

Appendix 1 B: ANOVA for organic matter at soil depth 10-20 cm

Source of Variation	Degree of freedom	Sum of Squares	Mean Squares	Observed F	F-Table
Total	7	4.56			
Treatment	1	3.03	3.03	11.65	5.99
Error	6	1.53	0.26		

Appendix 1C: ANOVA for organic matter at soil depth20-30 cm

Source of Variation	Degree of freedom	Sum of Squares	Mean Squares	Observed F	F-Table
Total	7	11.17			
Treatment	1	6.77	6.77	9.27	5.99
Error	6	4.40	0.73		

Appendix 1 D: ANOVA for organic matter at soil depth 30-40 cm

Source of Variation	Degree of freedom	Sum of Squares	Mean Squares	Observed F	F-Table
Total	7	4.62			
Treatment	1	2.43	2.43	6.59	5.99
Error	6	2.19	0.17		

Appendix 1 E: ANOVA for organic matter at soil depth 40-50 cm

Source of Variation	Degree of freedom	Sum of Squares	Mean Squares	Observed F	F-Table
Total	7	3.48			
Treatment	1	1.99	1.99	7.96	5.99
Error	6	1.49	0.25		

Appendix 2 A: ANOVA for clay content at soil depth 0-10 cm

Source of Variation	Degree of freedom	Sum of Squares	Mean Squares	Observed F	F-Table
Total	7	83.87			
Treatment	1	1.12	1.12	0.08	5.99
Error	6	82.75	13.79		

Appendix 2B: ANOVA for clay content at soil depth of 10- 20 cm

Source of Variation	Degree of freedom	Sum of Squares	Mean Squares	Observed F	F-Table
Total	7	109.87			
Treatment	1	28.13	28.13	2.07	5.99
Error	6	81.74	13.62		

Appendix 2 C: ANOVA for clay content at soil depth of 20 -30 cm

Source of Variation	Degree of freedom	Sum of Squares	Mean Squares	Observed F	F-Table
Total	7	463.5			
Treatment	1	18.0	18.0	0.24	5.99
Error	6	445.5	74.25		

Appendix 2 D: ANOVA for clay content at soil depth of 30-40 cm

Source of Variation	Degree of freedom	Sum of Squares	Mean Squares	Observed F	F-Table
Total	7	199.5			
Treatment	1	12.5	12.5	0.40	5.99
Error	6	187.0	31.17		

Appendix 2 E: ANOVA for clay content at soil depth of40-50 cm .

Source of Variation	Degree of freedom	Sum of Squares	Mean Squares	Observed F	F-Table
Total	7	249.87			
Treatment	1	15.13	15.13	0.39	5.99
Error	6	234.74	39.12		

Appendix 3 A: ANOVA for sand content at 0-10 cm depth

Source of Variation	Degree of freedom	Sum of Squares	Mean Squares	Observed F	F-Table
Total	7	159.87			
Treatment	1	55.13	55.13	3.16	5.99
Error	6	104.74	17.46		

Appendix 3 B: ANOVA for sand content at 10-20 cm depth

Source of Variation	Degree of freedom	Sum of Squares	Mean Squares	Observed F	F-Table
Total	7	128.87			
Treatment	1	66.12	66.12	6.32	5.99
Error	6	62.75	10.46		

Appendix 3 C: ANOVA for sand content at 20-30 cm depth

Source of Variation	Degree of freedom	Sum of Squares	Mean Squares	Observed F	F-Table
Total	7	196.87			
Treatment	1	45.12	45.12	1.87	5.99
Error	6	151.75	25.29		

Appendix 3 D: ANOVA for sand content at 30-40 cm depth

Source of Variation	Degree of freedom	Sum of Squares	Mean Squares	Observed F	F-Table
Total	7	177.5			
Treatment	1	12.5	12.5	0.45	5.99
Error	6	165	27.5		

Appendix 3 E: ANOVA for sand content at 40-50 cm depth

Source of Variation	Degree of freedom	Sum of Squares	Mean Squares	Observed F	F-Table
Total	7	75.87			
Treatment	1	10.12	10.12	0.92	5.99
Error	6	65.75	10.96		

Appendix 4 A: ANOVA for silt content at 0-10 cm depth

Source of Variation	Degree of freedom	Sum of Squares	Mean Squares	Observed F	F-Table
Total	7	186.0			
Treatment	1	18.0	18.0	0.64	5.99
Error	6	168.0	28.0		

Appendix 4 B: ANOVA for silt content at 10-20 cm depth

Source of Variation	Degree of freedom	Sum of Squares	Mean Squares	Observed F	F-Table
Total	7	116.0			
Treatment	1	8.0	8.0	0.44	5.99
Error	6	108.0	18.0		

Appendix 4 C: ANOVA for silt content at 20-30 cm depth

Source of Variation	Degree of freedom	Sum of Squares	Mean Squares	Observed F	F-Table
Total	7	98.87		.	
Treatment	1	66.12	66.12	12.11	5.99
Error	6	3.76	0.63		

Appendix 4 D: ANOVA for silt content at 30-40cm-soil depth

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Observed F	F-Table
Total	7	98.0			
Treatment	1	0.0	0.0	6.8	5.99
Error	6	98.0	16.33		

Appendix 4 E: ANOVA for silt content at 40-50cm soil depth

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Observed F	F-Table
Total	7	200.0			
Treatment	1	2.0	2.0	0.06	5.99
Error	6	198.0	33.0		

Appendix 5 A: ANOVA for water holding capacity at 0-10cm soil depth

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Observed F	F-Table
Total	7	4.13			
Treatment	1	0.1.71	1.71	4.28	5.99
Error	6	2.42	0.40		

Appendix 5B: ANOVA for water holding capacity at 10-20cm-soil depth

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Observed F	F-Table
Total	7	4.11			
Treatment	1	0.84	0.84	5.99	5.99
Error	6	3.27	0.55		

Appendix 5C: ANOVA for water holding capacity at 20-30 cm soil depth

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Observed F	F-Table Probability
Total	7	5.87			
Treatment	1	0.45	0.45	0.50	5.99
Error	6	5.42	0.90		

Appendix 5 D: ANOVA for water holding capacity at 30-40 cm soil depth

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Observed F	F-Table Probability
Total	7	5.04			
Treatment	1	1.28	1.28	2.03	5.99
Error	6	3.76	0.63		

Appendix 5E: ANOVA for WHC at 40-50 cm soil depth

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Observed F	F-Table Probability
Total	7	2.48			
Treatment	1	0.25	0.25	0.68	5.99
Error	6	2.23	0.37		

Appendix 6A: ANOVA for Bulk density at 0-10 cm soil depth

Source of Variation	Degree of freedom	Sum of Squares	Mean Squares	Observed F	F-Table Probability
Total	7	0.34			
Treatment	1	0.17	0.17	6.07	5.99
Error	6	0.17	0.028		

Appendix 6 B: ANOVA for Bulk density at 10-20 cm soil depth

Source of Variation	Degree of freedom	Sum of Squares	Mean Squares	Observed F	F-Table Probability
Total	7	0.01			
Treatment	1	0.01	0.01	0.07	5.99
Error	6	0.82	0.14		

Appendix 6 C : ANOVA for Bulk density at 20-30cm soil depth

Source of Variation	Degree of freedom	Sum of Squares	Mean Squares	Observed F	F-Table Probability
Total	7	0.16			
Treatment	1	0.08	0.08	6.15	5.99
Error	6	0.08	0.013		

Appendix 6 D: ANOVA for Bulk density at 30-40 cm soil depth

Source of Variation	Degree of freedom	Sum of Squares	Mean Squares	Observed F	F-Table
Total	7	0.06			
Treatment	1	0.03	0.03	6.00	5.99
Error	6	0.03	0.005		

Appendix 6 E: ANOVA for Bulk density at 40-50 cm soil depth

Source of Variation	Degree of freedom	Sum of Squares	Mean Squares	Observed F	F-Table
Total	7	0.20			
Treatment	1	0.07	0.07	3.50	5.99
Error	6	0.13	0.02		